

Received June 8, 1769.

XXX. *A Letter from Mr. Lane, Apothecary, in Aldersgate-street, to the Honourable Henry Cavendish, F. R. S. on the Solubility of Iron in simple Water, by the Intervention of fixed Air.*

Aldersgate-street, June 5, 1769.

S I R,

Read Nov. 23, 1769. **T**HE various impregnations of mineral waters have always been very difficult to explain : and whoever has read the divers, and often contradictory reasonings upon the subject, must clearly perceive, that there is still room for discoveries in this part of natural history.

You, Sir, by your accounts of fixed air, and of Rathbone-place water, related in the last volume of Philosophical Transactions, have obliged the public with many additional lights on this branch of knowledge ; and, from your known accuracy, and diligent pursuits in most philosophical inquiries, the learned world has great reason to hope for many other new and useful improvements. To your judgment therefore, I submit the following experiments ; which are intended to shew, that iron is soluble in simple water,  
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by the intervention of fixed air; and thence, that it is very probable, many different chalybeate springs sustain their metallic charge by this means only.

The solution of iron in mineral waters, especially in such as, by exposure, readily lose the property of striking a purple colour with astringent vegetables, has usually been attributed to some subtile gas, or volatile acid. Chymistry, however, does not discover any acid solvent for iron, but what has greater affinity with alcalies; and by means of which, therefore, this metal will be precipitated. Hence if any water appears, with a predominant alkali, which has also the power of tinging with galls, and, on being exposed to the open air, lets fall the iron, and loses that property; may we not conclude the metal to have been suspended by some other medium?

This, for example, is plainly the case in German Spa water, which Dr. Brownrigg has proved to abound with fixed air. Your own very curious experiments, before cited, have clearly shewn, that calcarious earths may be suspended in water by this principle of fixed air. And these have led me to examine, whether iron might not be dissolved by the same natural means.

I would not, however, be supposed to deny, that iron is frequently found united with an acid. The fact is sufficiently evinced in the pyrites and vitriolic earths. Nor can I doubt, but that these substances do largely contribute to the primary impregnation of waters, they being so readily soluble in them. But as an alkali, or absorbent earth, is often found more than sufficient to saturate the acid in mineral waters; this would effectually disengage every

particle of iron dissolved by an acid, unless the metal was supported by some other menstruum.

My endeavours, therefore, to detect this solvent, by experiments, are what I now beg leave to lay before you, in the order I made them.

### EXPERIMENT I.

A wide-mouthed bottle, containing half a pint of distilled water and sixty grains of steel-filings, was suspended forty-eight hours over some distillers melasses, in brisk fermentation; so as to receive the fixed air escaping from the fermenting liquor; the surface of which was ten inches below the mouth of the bottle. Immediately after its removal, the clear water was decanted from the filings and ochrous sediment.

This liquor had a brisk and ferruginous taste, with a flavour of the melasses. An infusion of galls, or green tea, soon changed part of it to a colour like ink. The remainder, being exposed to the open air, presently became turbid, threw up a party-coloured pellicle, and deposited a yellowish sediment.

The water now retained but very little power of tinging with galls; and in a few days lost this property entirely.

### EXPERIMENT II.

Fourteen ounces of coarse sugar, dissolved in seven pints of water, were mixed with half a pint of yeast, in a bottle capable of holding more than twice the above quantity. One end of a bent tube was luted into this vessel, so that no air might escape but through  
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the tube; the other end was loosely inserted two inches within the mouth of another large bottle, charged with four hundred grains of iron filings, and sixty ounces of distilled water. After remaining twelve hours in this situation, the sugar working briskly, an ounce phial was let down gently into the bottle, and filled. The water from the phial, with one drop of tincture of galls \*, changed in a few minutes to a light rosy purple. The liquor being shaken, and another phial-full taken up soon after, one drop of the tincture gave a deeper colour than before. In an hour and half more, after being shaken again, the phial-full received a still deeper purple, from the like quantity of tincture. The bottle continuing as before near five hours longer; when the quantity of fixed air from the fermenting liquor was supposed sufficient to have saturated the water; the liquor appeared very turbid on being shaken; and, after standing another hour, under the tube, to settle, the whole was filtered.

Thirty ounces of the clear liquor was poured into two Florence flasks, and the remainder into phials, which were afterwards well corked. Two of these phials had their corks dipped into melted resin, so as to cover the mouths of the bottles. Two others were enclosed with a paste or lute.

Notwithstanding the above precautions to prevent the escape of air, the liquors in each soon grew turbid, and by the next morning deposited yellow sediments.

\* This tincture was made by infusing half an ounce of powdered galls in eight ounces of proof spirit, for four days, without heat.

This water had a smart chalybeate taste, somewhat resembling Spa water ; with a slight flavour of the fermenting liquor.

One drop of tincture of galls gave a rosy purple colour to a wine-pint of this water.

Syrup of violets turned it green \*.

Soap leys, or even alkaline salts, either fixed or volatile in their natural states, soon changed this liquor green, and rendered it turbid, whence a yellow sediment ensued.

But neither of the alkaline salts, when previously saturated with fixed air, produced any perceptible alteration.

Nor did any visible change happen on the addition of acids.

The thirty ounces of water, in the flasks before mentioned, after being boiled twenty minutes, to expel the air, became very turbid, and let fall sediments. The clear liquor being decanted, the remainder was passed through a filter, and, after drying, the paper appeared to have gained two grains and a quarter.

This ochrous residuum could not be again dissolved in water, by means of fixed air ; but was soluble in the vitriolic acid. The solution, diluted and filtered, received no colour from galls, until alkali was added to saturate the redundant acid ; after which it struck a purple, as in common solutions of iron.

\* Simple distilled water, saturated with fixed air, by any means I have tried, makes no change in syrup of violets : and, when mixed with soap, does not curdle.

The liquor, decanted after boiling, neither changed colour with galls, nor shewed any precipitation with lime-water.

### EXPERIMENT III.

A common quart-bottle was half filled with distilled water, to which were added an hundred grains of steel-filings. To these was introduced, by means of the bent tube, as much fixed air, obtained from a solution of alkaline salt in the vitriolic acid, as was judged sufficient to fill the bottle. The whole being then shaken, with my hand over its mouth, the bottle stuck like a cupping-glass. About the same quantity of air being again added, the bottle, after shaking, had less adhesion than before. On repeating this experiment, a third time, with fresh air, the adhesion was scarcely perceptible. And after the fourth trial, a small portion of air was observed to issue from the bottle. The water now gave a deep colour with tincture of galls.

This experiment was repeated with fixed air from different combinations. As also by passing this air through a vessel of pearl-ash, to arrest any acid which might escape from the effervescent mixtures. But the solutions of iron, in all the trials, appeared to be exactly similar, except some trifling difference in taste and smell.

### EXPERIMENT IV.

A bottle, with the like quantity of steel-filings and distilled water as in Experiment the First, remained  
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in a room many weeks; yet although it was frequently shaken, and had an ochrous sediment, it gave no colour with tincture of galls,

### EXPERIMENT V.

A single grain of iron in solution\*, diluted with a pint of distilled water, changed to a deep blue purple, with the tincture of galls. Half a pint of the like mixture, exposed many days in a wide-mouthed glass covered loosely with paper, let fall a slight precipitation; but its property of tinging with galls was not sensibly diminished. The same quantity being boiled four or five minutes, in a Florence flask, became turbid, and deposited a small portion of an ochrous sediment. The tincture of galls, nevertheless, gave as deep a colour to the clear liquor, as it would have done before boiling.

The foregoing experiments seem to prove, that iron remains quite unaffected by pure water, but may easily be dissolved in it on the addition of fixed air; and that in whatsoever manner this air is generated, the event will appear the same. The last experiment shews, that where iron is suspended in water, by an acid, neither exposure nor boiling will destroy its property of tinging with galls; which is the reverse of what we find to be the case with many ferruginous waters. Experiment the Second more particularly

\* Iron-filings were dissolved in diluted oil of vitriol to saturation; and, by experiment, one grain of the metal, with about two grains and a quarter of the acid, were found to be contained in sixty-eight grains of the solution.

teaches, that the iron, dissolved in water by fixed air, is at least equal in quantity to what is commonly ascribed to most chalybeate springs: that this air, by which the metal is held in solution, is similar to that elastic vapour, so often mentioned by writers on these subjects; which cannot be wholly retained by the closest corking, but, gradually escaping, suffers the ochrous matter to subside. And that fixed air has greater affinity with alcalies than with iron, because addition of alkaline substances, not saturated with fixed air, will disengage the metal, while such as are charged with this principle produce no alteration.

These conclusions seemed to account for many particulars relating to medicated springs; but as all my trials had been made with iron in its metallic state, which is rarely found in nature, it was necessary to repeat them upon this mineral in the state of ore. I proceeded, therefore, to different experiments upon various ores; but did not find any of them to answer my expectation, except what is called iron sand ore, which seems to contain a perfect iron.

This, at first, offered a material objection to my former inference. But, upon a little consideration, it occurred, that waters, being first charged with pyritical matter, might afterwards have their acid neutralized with alkaline or calcarious substances, and the iron yet remain suspended by air generated in the saturation. And I was the more ready to adopt this opinion, as it would explain, very naturally, the application of fixed air to this business of solution; which, I confess, had hitherto been to me somewhat difficult to account for. It was necessary, however, to examine the truth of this theory, by  
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the test of experiment, which I did in the following manner.

### EXPERIMENT VI.

To a pint of distilled water, mixed with one grain of iron dissolved (as in Experiment the Fifth), were added forty grains of soap leys.

And to two ounces of lime-water, diluted with fourteen ounces of distilled water, was added a grain of iron in solution.

In both cases the point of saturation was intended. The two mixtures instantly turned green, grew turbid, and let fall sediments of the same colour. The liquors, being filtered, gave no tinge with tincture of galls.

### EXPERIMENT VII.

A quart of water was mixed with two grains of iron, as before.

To one moiety, three grains of salt of tartar in solution was infilled. It first appeared green, soon changed yellow, and gave an orange-coloured precipitate.

To another portion two grains of powdered chalk being added, it presently became straw-coloured, and after continuing nine hours in a well-corked phial, was yet turbid, with a yellow sediment.

The waters being both filtered, part of each changed to a purple, with tincture of galls. The remainder being boiled, a farther precipitation ensued, and the clear liquor no longer produced any alteration with galls.

This experiment being repeated with magnesia, and with the earth of alum, shewed no sensible difference.

The quantity of iron, left dissolved in the liquor, was found in proportion to the volume of air generated during the saturation.

If the quantity of alcali or absorbent earth was insufficient to saturate the acid, part of the iron would remain in the water after boiling. All which were discoverable by the tincture of galls.

### EXPERIMENT VIII.

To a pint of distilled water, being saturated with fixed air, and containing four grains of chalk, was added a grain of iron in solution; the mixture continued pellucid.

Another grain of dissolved iron was diluted with a like quantity of water, previously saturated with air from a solution of pearl-ash in vitriolic acid: eight grains of salt of tartar, crystallized with fixed air, and dissolved, were added to this mixture: a slight degree of cloudiness ensued, but disappeared on shaking; after which the liquor much resembled Spa-water; only it tasted stronger of the iron. The quantity of chalk, and alkaline salt, in this experiment, was more than sufficient to neutralize the acid.

Both the above mixtures, on exposure, became turbid, threw up pellicles, deposited ferruginous sediments, and lost their power of striking a purple with galls.

Solutions of iron, and of its ores, in the marine and nitrous acids, as also pyrites dissolved in rain-water, were substituted, by turns, instead of the original iron in vitriolic acid; and they all gave a purple colour with tincture of galls.

The trials were repeated with lime-stone, marble, island crystal, osteocolla, and magnesia, in lieu of chalk; and with volatile and mineral alcali, replete with air, in the room of salt of tartar; but no material difference was observed.

The success of these experiments completely answered my expectations. They satisfied me, that any acid holding iron dissolved, and diluted with water, might not only be neutralized, but the water charged with an excess of alkaline or earthy matter, without precipitating the metal; and that the solvent, in these cases, could be no other than *Fixed Air*. Since the iron remained in solution, only where this principle originally abounded in the water, or was afterwards generated in the saturation.

Thus much being determined, it seemed easy to apply the discovery to the more perfect analyzation of some waters; and to the re-production of others, by art, which should exactly resemble those of natural medicated springs. This is a task I should probably have undertaken at leisure; had I not been informed, that Dr. Watson, junior, by whose conversation my thoughts were first led to the subject, is already engaged in something of this sort. This gentleman saw many of the foregoing experiments repeated; and, as he is since gone to the German Spa, I dare say, his abilities and application will sufficiently improve the

the opportunity: I shall gladly, therefore, wait the result of his enquiries.

To conclude then: It appears to me highly probable, that fixed air is generally necessary to the impregnation of mineral springs. That by the right knowledge of this principle, we may now solve most difficulties that have arisen on this subject; and very possibly be able, hereafter, to imitate nature, in the formation of medicated waters. Whether my conclusions are well founded, I with pleasure refer to your candid decision. And am,

S I R,

with great respect,

Your much obliged,

humble servant,

T. Lane.